A total dissolved solids budget for the experimental wetland basins, 1996-98

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A budget for the inflow and outflow of total dissolved solids in the experimental basins of the Olentangy River Wetland Research Park was developed for the years 1996-1998.

Methods

Total dissolved solids concentrations (mg/L) can be calculated from conductivity measurements (μS/cm) using an empirical factor which ranges from 0.5 to 0.9 (APHA 1989, Method 2510 A). However, this factor must be corrected for temperature effects, as conductivity increases with increasing temperature. Twenty-four 1-L water samples were taken in November 1999 from the inflow, middle, and outflow of the wetlands, and conductivity and temperature measurements were made concurrently using a YSI 610-D (YSI, Inc., Yellow Springs, OH). Samples were taken back to the laboratory and 300-400 mL of each sample was immediately filtered through a 0.45 μm cellulose filter. Two-hundred - mL subsamples of the filtrate were placed into preweighed erlenmeyer flasks, which were then dried at 105 ^oC. Subsamples were cooled in a desiccator and reweighed. The remaining water samples were then placed in water baths to change their temperature, and their conductivity and temperature were measured several more times to determine the effects of temperature on the empirical ratio mentioned above.

From these water samples, 48 data points were used to determine the empirical relationship among temperature, total dissolved solids and conductivity (Figure 1). A single linear equation was calculated for 0-40 ^oC (Figure 1a).

$$TDS = SC*(1.05069 - 0.01583*T) \quad (1)$$

$(r^2=0.9101, n=48)$

where

TDS = total dissolved solids, mg/L)

SC = specific conductance in μS/cm)

T = temperature, ^oC

However, the data were better described by a second-order equation (Fig 1b).

Two data points were discarded as outliers, and the following equation was calculated:

$$TDS = SC*(0.0003655 *T^2 - 0.03156*T + 1.17385) \quad (2)$$

$(r^2=0.9814, n=46)$

Using equation 2, the TDS concentrations in the inflow and outflow of each basin were calculated from specific conductance and temperature data taken twice daily at the inflow and outflow of the wetland basins from 1996 to 1998. The TDS concentrations in the middle subbasins were calculated from specific conductance and temperature data taken by YSI 6000 datasondes from July 1996 to December 98.

Calculating the TDS outflow from the wetlands via groundwater required making some assumptions, as there were no conductivity data available for groundwater outflow. The TDS concentrations leaving each subbasin via groundwater were assumed to be equal to the concentrations in the surface water of each subbasin. When only inflow and outflow data were available, it was assumed that the concentration of total dissolved solids in the groundwater outflow was equal to the average of the TDS concentrations at the inflow and outflow of the wetlands.

$$[TDS]_{gw} = ([TDS]_{in} + [TDS]_{out})/ 2 \quad (3)$$

where

$[TDS]_{gw}$ = the concentration of total dissolved solids in the groundwater, g m^{-3}.

$[TDS]_{in}$ = concentration of TDS at the inflow of the wetland, g m^{-3}

$[TDS]_{out}$ = concentration of TDS at the surface outflow of the wetland, g m^{-3}

When only data from the middle subbasins were available, the groundwater leaving the wetlands was assumed to have the same concentration as the middle subbasins.

The amount of groundwater leaving the wetlands via each subbasin was calculated from the total groundwater outflow according to the area of each subbasin.

$$Q_{gw(subbasin)} = Q_{gw} A_{subbasin} / A_{total} \quad (4)$$

where

$Q_{gw(subbasin)}$ = the total water flowing out a particular subbasin, $m^3 d^{-1}$

Q_{gw} = the total flow of groundwater leaving the wetland, $m^3 d^{-1}$

$A_{subbasin}$ = the area of a particular subbasin, m^2

A_{total} = the total area of the wetland basin, m^2

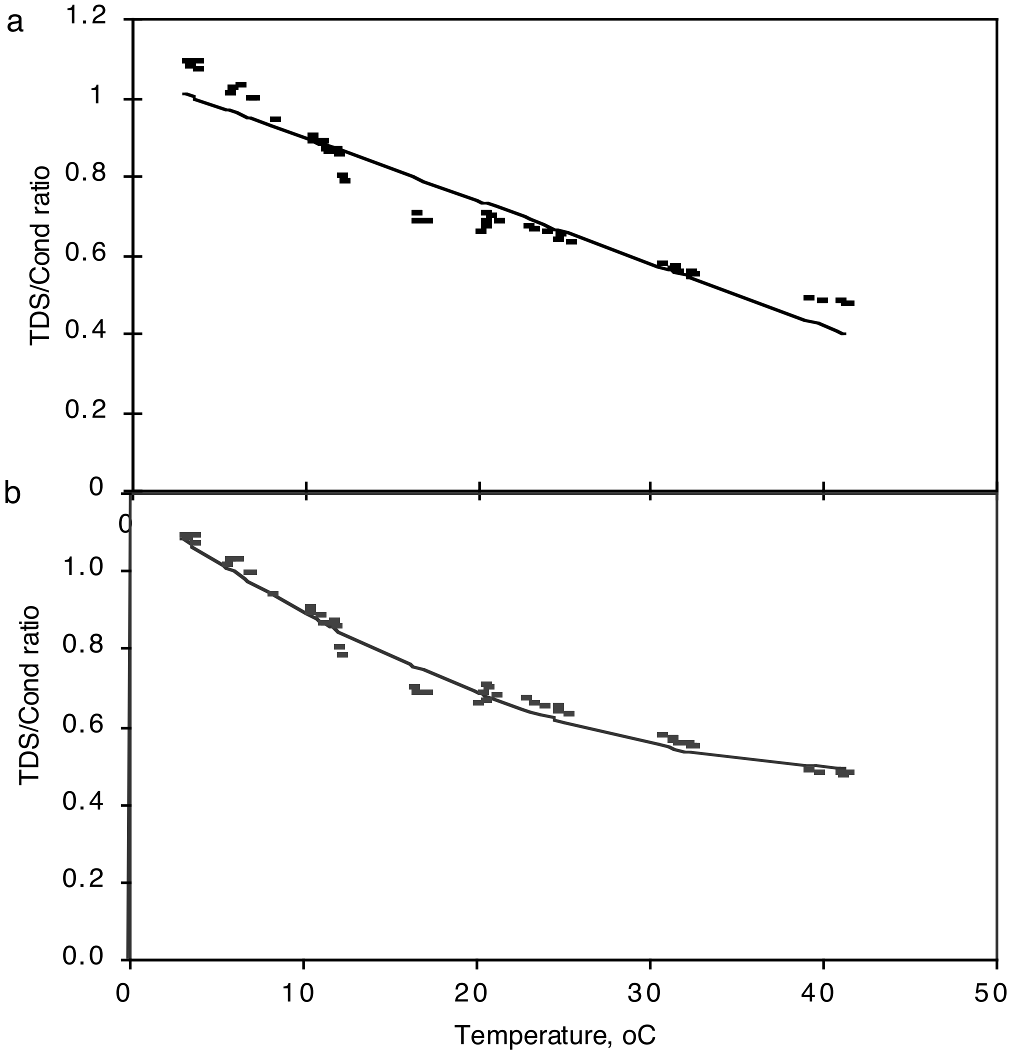

Figure 1. Regressions for the temperature-dependent empirical relationship between conductivity and total dissoved solids. a) a linear regression for the entire temperature range. This model was discarded in favor of b) a second-order equation.

Using this method, the inflow and outflow subbasins each accounted for approximately 25% of the total groundwater flow, and the middle subbasin accounted for approximately 50 % of the total groundwater flow. The daily mean TDS concentrations were multiplied by the daily volume of surface water and groundwater flowing into and out of the wetlands, obtained from yearly water budget calculations (Wang et al,. 1997, Wang et al., 1998, Wang and Mitsch, 1999).

$$TDS_{in} = [TDS]_{in} * Q_{in} \quad (5)$$

$$TDS_{out} = [TDS]_{out} * Q_{out} \quad (6)$$

$$TDS_{gw} = [TDS]_{in} * Q_{gw(in)} + [TDS]_{mid} * Q_{gw(mid)} + [TDS]_{out} * Q_{gw(out)} \quad (7)$$

where

TDS_{in} = the daily sum of total dissolved solids entering the wetland, g d^{-1}

Q_{in} = the total flow of surface water entering the wetland, m^3 d^{-1}

TDS_{out} = the daily sum of TDS leaving the wetland through surface water, g d^{-1}

Q_{out} = the total flow of surface water leaving the wetland, m^3 d^{-1}

TDS_{gw} = the daily sum of TDS leaving the wetland through groundwater, g d^{-1}

$Q_{gw(in)}$ = the total flow of groundwater leaving the inflow subbasin, m^3 d^{-1}

$Q_{gw(mid)}$ = the total flow of groundwater leaving the middle subbasin, m^3 d^{-1}

$Q_{gw(out)}$ = the total flow of groundwater leaving the outflow subbasin, m^3 d^{-1}

These daily values were summed for each month.

$$TDS_{in(T)} = STDS_{in} \quad (8)$$

Table 1. Total dissolved solids budget in megagrams (Mg) per year for the 1-ha experimental wetland basins at the Olentangy River Wetland research Park, 1996-98.

Wetland 1

Year	Surface inflow Mg/yr	Surface outflow Mg/yr	Groundwater outflow Mg/yr	Retention Mg/yr	Retention %
1996	90.6	62.8	21.1	6.7	7.4
1997	173.9	130.5	44.1	-0.7	-0.4
1998	159.4	141.1	6.9	11.3	7.1

Wetland 2

Year	Surface inflow Mg/yr	Surface outflow Mg/yr	Groundwater outflow Mg/yr	Retention Mg/yr	Retention %
1996	94.6	63.8	18.1	12.7	13.5
1997	173.9	120.1	45.4	8.4	4.8
1998	158.9	124.5	25.6	8.8	5.5

$$TDS_{out(T)} = STDS_{out} \quad (9)$$
$$TDS_{gw(T)} = STDS_{gw} \quad (10)$$

where

$TDS_{in(T)}$ = the raw monthly sum of TDS entering the wetland in surface water, g month^{-1}

$TDS_{out(T)}$ = the raw monthly sum of TDS leaving the wetland in surface water, g month^{-1}

$TDS_{gw(T)}$ = the raw monthly sum of TDS leaving the wetlandin groundwater, g month^{-1}

To correct for missing data days, these monthly totals were multiplied by a correction factor, C_m., for each type of flow (surface inflow, surface outflow, groundwater outflow)

$$C_m = Q/Q_{cond} \quad (11)$$

where

Q = monthly total water flow, m^3

Q_{cond} = total water flow on days with available conductivity data, m^3

These corrected monthly totals were summed for the entire year to determine the percent retention of total dissolved solids in the wetland basins.

Results

The TDS budget shows that the ORWRP basins vary in their removal efficiency for dissolved solids from year to year (Table 1). In 1996 the two wetlands retained 7.4 and 13.5 percent of the total dissolved solids entering them. In 1997, Wetland 1 was approximately in steady state, with a very small calculated export of dissolved solids (0.4 percent), while Wetland 2 retained 4.8 percent of the TDS entering it. Both wetlands retained dissolved solids (7.1 and 5.5 percent, respectively) in 1998.

The variation in dissolved solids entering the wetlands is a function of two factors: natural variation in seasonal river flow (and thus pumping rate, which is regulated to mimic natural inputs from the river) from year to year, and mechanical failures of the pumps bringing water from the Olentangy River into the wetlands. In 1996, due to mechanical problems, the pumps were not pumping for 146 days over the course of the year. Most of the non-inflow time occurred in January, February, and May. In 1997 and 1998 the pumps were off for only 28 days each year. The highest percent retention of TDS occurred during 1996, the low-flow year.

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